

Production and Performance Evaluation of Diesel Engine Using Biodiesel from Pongamia Oil

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Abstract

Every sector of Indian economy- agriculture, industry, transport, commercial and domestic needs input of energy. The economic development plans implemented since independence have necessarily required increasing amount of energy. As a result consumption of energy in all forms has been steadily rising all over the country. The energy demand is increasing at a rate of 6.5% per annum. The crude oil demand of country is met by import of about 70%. Thus the energy security has become key issue for our country. In view of the fast depletion of fossil fuel, the search for alternative fuels has become inevitable, looking at huge demand of diesel for transportation sector, captive power generation and agricultural sector, the biodiesel is being viewed a substitute of diesel. The aim of the present work is to focus on the work done in the area of production of biodiesel from Pongamia and the characterization of properties of various blends of Pongamia biodiesel. The work also includes the impact analysis of Pongamia oil and its biodiesel on engine performance and exhaust emission. The results obtained are also compared with the *Jatropha curcas* biodiesel and Waste cooking biodiesel. The research has indicated that up to B₂₀, there is no need of any modification. From the test result it is found that the use of biodiesel leads to the substantial reduction in particulate emission, CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NO_x emission on conventional diesel engine with no or fewer modification. So from the result it can be observed that biodiesel will replace diesel as a source of fuel in near future.

Keywords

Biodiesel; Methanol; Pongamia; Jatropha

Introduction

In IC engine, the thermal energy is released by burning the fuel in the engine cylinder. The combustion of fuel

in IC engine is quite fast but the time needed to get a proper air/fuel mixture depends mainly on the nature of fuel and the method of its introduction into the combustion chamber. The combustion process in the cylinder should take as little time as possible with the release of maximum heat energy during the period of operation. Longer operation results in the formation of deposits which in combination with other combustion products may cause excessive wear and corrosion of cylinder, piston and piston rings. The combustion product should not be toxic when exhausted to the atmosphere. These requirements can be satisfied using a number of liquid and gaseous fuels. The biodiesel from non edible sources like *Jatropha*, *Pongamia*, *Mahua*, *Neem* etc meets the above engine performance requirement and therefore can offer perfect viable alternative to diesel oil in India. the experiment on the diesel engine are performed and found out that it increase the BSFC using various blends of biodiesel from various resources including diesel. The finding indicates that there is increase in the BSFC when using biodiesel as compared to diesel for the same power output. This is because that the heating value of biodiesel is less as compared to diesel (Baiju, Naik, Das 2009). It is found that there is no significant change in the thermal efficiency while using biodiesel up to B₂₀ but there is a slight decrease in thermal efficiency when B₁₀₀ was used which is due to the lower energy content of biodiesel (Banapurmatha, Tewaria and Hosmath 2008). Literature revealed that the engine operation on biodiesel blend with diesel emit lower gaseous emission than diesel fuel expect NO_x which increase to 2% with B₂₀ and 10% with B₁₀₀ use.

Pongamia Oil Collection

Pongamia oil was purchased from Bangalore

Analytical grade chemicals were used for the reaction.

TABLE 1 FATTY ACID COMPOSITION OF JATROPHA CURCAS OIL AND PONGAMIA OIL

Fatty Acid	Formula	Structure	Net % for Jatropha	Net% for Pongamia Oil
Lauric acid	C ₁₂ H ₂₄ O ₂	C ₁₂	-	-
Myristic acid	C ₁₄ H ₂₈ O ₂	C ₁₄	0–0.1	-
Palmitic acid	C ₁₆ H ₃₂ O ₂	C ₁₆	14.1–15.3	6.8
Palmitoleic acid	C ₁₆ H ₃₀ O ₂	C _{16:1}	0–1.3	-
Stearic acid	C ₁₈ H ₃₆ O ₂	C ₁₈	3.7–9.8	6.7
Oleic acid	C ₁₈ H ₃₄ O ₂	C _{18:1}	34.3–45.8	51
Linoleic acid	C ₁₈ H ₃₂ O ₂	C _{18:2}	29.0–44.2	27.1
Linolenic acid	C ₁₈ H ₃₀ O ₂	C _{18:3}	0–0.3	6.3
Arachidic acid	C ₂₀ H ₄₀ O ₂	C ₂₀	0–0.3	0.8
Behenic acid	C ₂₂ H ₄₄ O ₂	C ₂₂	0–0.2	1.2
Gadoleic acid	C ₂₄ H ₄₈ O ₂	C ₂₄	14	-
Saturates	-	-	21.1	15.5
Unsaturates	-	-	78.9	84.4

The fatty acid composition of Jatropha and Pongamia oil is shown in table. 1 which shows that both the oils are composed of mainly unsaturated fatty acids. Due to this reason the oxidation stability of both the biodiesel is very severer thereby the resulting biodiesel is unstable in its fuel characteristics.

Experimental Setup for Biodiesel Production

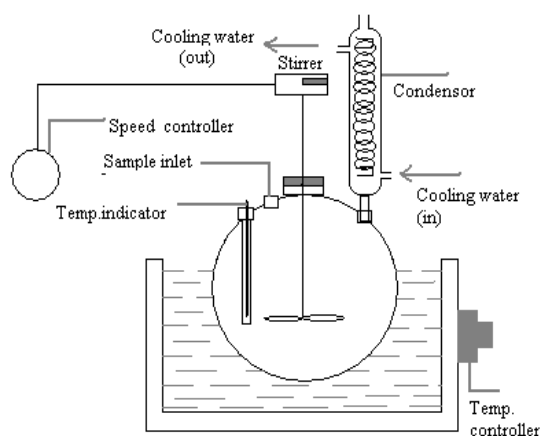


FIG. 1 SCHEMATIC OF TRANSESTERIFICATION REACTOR

The single step base transesterification process was adopted for the production of biodiesel. The experiments were conducted in a batch reactor of 1.5 liter capacity made of borocil glass equipped with provision of condenser, stirrer, inlet & outlet for sample withdrawing and temperature measurement device, i.e., a digital temperature indicator cum

controller. All the setup was put up in constant temperature water bath with precision of $\pm 0.5^\circ\text{C}$. The schematic of the experimental setup is shown in Fig. 1.

Procedure for Biodiesel Production

A batch reactor of 1.5 litre capacity as shown in Fig.1 was used for production of biodiesel from Pongamia oil. Methanol was chosen as the alcohol for transesterification of oil because of its lower cost and lower viscosity. The FFA contents of the oils is as 2%. Owing to low FFA content base catalyzed transesterification processes was adopted. For this purpose a mixture of methanol (30% v/v) and NaOH (1% w/w of oil) was prepared and heated at 50°C . This hot mixture was mixed with oil and stirred at 50°C for half hours. The mixture was allowed to settle down in separating funnel for overnight. The two layers were formed. The lower layer of glycerin was drained off by gravity, while the upper lighter layer was separated.

Methanol Separation

The methanol from the methyl ester layer was removed by vacuum distillation in Buchi evaporator and may be recycled for further biodiesel production. The process of biodiesel production is shown in Fig 2.

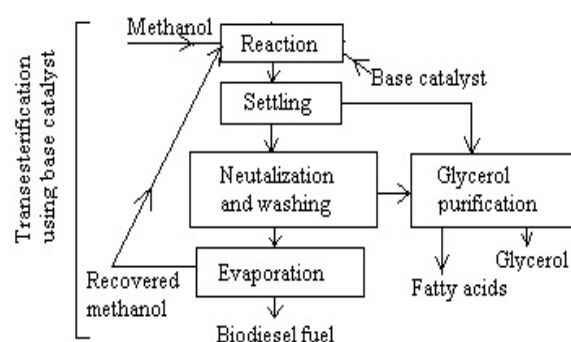


FIG. 2 PROCESS OF BIODIESEL PRODUCTION

Purification (Organic Phase) Biodiesel

The methyl ester phase was washed with fresh water thrice which removes the catalyst as well as the residual methanol (if any). During washing if the layer of methyl ester & water does not separate within 20-30 min, it indicates that the conversion of oil has not been taken place completely. The same process was repeated until lower layer appeared as transparent. Through, the biodiesel is separated. The rest dissolve water is removed finally by heating at 100°C for 1 hour. Now biodiesel is free from catalyst, methanol, water and other impurities. The pure biodiesel is stored in steel, aluminum/plastic or copper made container.

Fuel Properties of Pongamia Biodiesel

The measurement of fuel properties of various blends of Pongamia biodiesel and diesel is shown in the table 2.

TABLE 2 FUEL PROPERTIES OF VARIOUS BLENDS OF PONGAMIA BIODIESEL

Blends Properties	B10	B20	B50	B100	Diese 1	Equipment / Method Adopt
Density at 25(°C)	805	811	860	874	756	Gravimetri c method
Viscosity (cSt,@30°C)	3.6	6.4	13	19	2.5	Digital Viscometer
Flash Point (°C)	68	75	96	156	60	Pensky- martens apparatus
Calorific Value(kJ/kg)	4368 0	4154 6	3547 0	2944 2	4566 6	Bomb calorimeter

Experimental Setup for Engine Test

After preparation of various blends of biodiesel it is tested in engine to check the performance of engine. The experimental setup of engine is given in Fig 3.

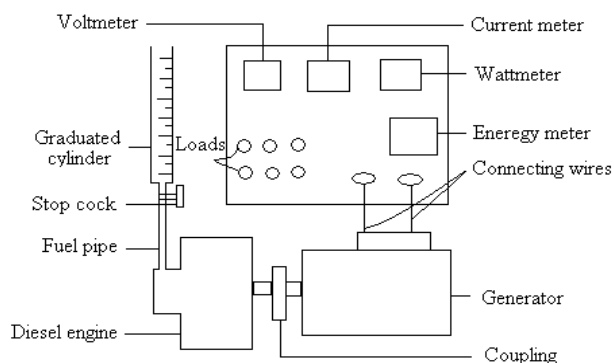


FIG. 3 SCHEMATIC OF EXPERIMENTAL SETUP

Diesel Engine

The kirloskar make single cylinder diesel engine-generating set of 2 kVA rating was used for experimentation. The technical details of engine are given in table 3. The filter of the diesel engine was disconnected from its diesel tank and connected directly to fuel measuring unit.

1) Generator

A single-phase synchronous generator of 2 kVA rating directly coupled to diesel engine has been used.

2) Fuel Measurement Unit

The fuel measurement unit consists of graduated glass cylinder as shown in Fig. 3. The top end of the cylinder was open and bottom end was fitted with stopcock. The outlet of stopcock was connected to the filter unit of the diesel engine by a PVC pipe. A schematic of the experimental set up is given in Fig. 3.

3) Resistive Type Load Panel

The resistive type load panel consists of voltmeter, current meter, wattmeter, and energy meter. The engine can be loaded up to 2.5 kW using incandescent bulbs of 100W each. A photograph of complete experimental setup is shown in the Fig.3.

The technical specification of diesel engine is given in the table 3 consisting of various parameters of engine.

TABLE 3 TECHNICAL SPECIFICATION OF DIESEL ENGINE

S.No.	Parameters	Details
1	Make and model	Kirloskar, AA35
2	Type of engine	Vertical, 4-stroke, single acting high speed compression ignition diesel engine
3	No of cylinder	
4	Rating @ 1500 rpm	2.6 kW (3.5 bhp)
5	Base	30 mm
6	Stroke	76 mm
7	Cubic capacity	0.382 liters
8	Compression ratio	15.6: 1
9	Duel timing for standard engine by spill (BTDC)	24°
10	BMEP @ 1500 rpm	5.5 kg/mm ²
11	Rated speed	1500 rpm
12	Direction of rotation	Clockwise when looking at fltwheel end
13	Inlet valve open BTDC	4.5°
14	Inlet valve closes @ ABDC	35.5°
15	Exhaust valve opens @ BBDC	35.5°
16	Exhaust valve closes ATDC	4.5°
17	Governor type	Mechanical, centrifugal type
18	Nozzle opening pressure	190-210 kg/cm ²
19	Fuel oil tank capacity	3.75 liters
20	Lube oil sump capacity	1.3 liters

4) Test Procedure

The engine was directly coupled to alternator and loaded by electrical resistance. The separate fuel measurement unit was connected with engine. A resistive load panel was attached with the output of the generator. The engine- generator set was run initially using diesel for 10 minutes each for 25, 50, 75 and 100% load. The fuel consumption was measured by using stopwatch. At the same time the reading of voltmeter, current meter and energy meter were also noted down. Different blends of Pongamia biodiesel with diesel were prepared namely B₁₀, B₂₀, B₃₀, B₄₀, B₅₀, and B₁₀₀. Before using

blend, each one was mixed thoroughly. The filter of diesel engine was opened and complete mixture of biodiesel and diesel was drained so that it could not mix with the next blend. The experiment was repeated for each blend.

Result and Discussions

BSFC of Biodiesel from Pongamia Oil

The graph reports the result of BSFC which states that as the load decreases the fuel consumption for different blends of biodiesel increases. The possible reason may be that, at lower loads, significant proportion of the fuel inducted through the intake does not burn completely due to lower quantity of pilot fuel, low cylinder gas temperature and lean fuel air mixture. Another reason may be that at higher load, the cylinder wall temperature is increased, which reduces the ignition delay leading to the improvement in combustion and reduction in fuel consumption. The trend of BSFC for different blends for biodiesel from Pongamia B₁₀ up to B₁₀₀ is shown in Fig. 4, which indicates that the highest BSFC for B₁₀₀ (759 g/kWh) at full load is about 30% higher than diesel (582 g/kWh). The reason for this is lower calorific value of Pongamia than diesel.

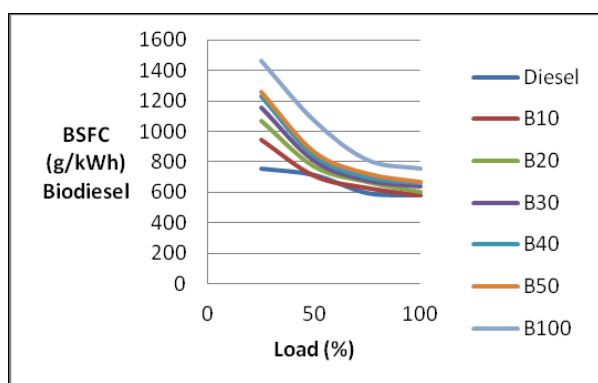


FIG. 4 VARIATION IN BSFC WITH LOAD (%) FOR DIFFERENT BLENDS OF BIODIESEL FROM PONGAMIA

The BSFC depends on fuel specific gravity, viscosity and calorific value. The specific gravity increases and calorific value decreases and more amount of fuel is needed to produce the same amount of energy. As the Pongamia biodiesel proportion in blend is increased BSFC also increase. As it is clear from the results BSFC for B₁₀ (580 g/kWh) which is almost equal to the diesel, (601 g/kWh) for B₂₀, (642 g/kWh) for B₃₀, (661 g/kWh) for B₄₀, (669 g/kWh) for B₅₀ is respectively 3.2, 10.3, 13.5 and 14.9% respectively higher than diesel. The BSFC of B₁₀ is same as that of diesel. The reason may be due to high viscosity higher volumetric fuel delivery of fuel per stroke of the engine. Another reason may be due to presence of inherent oxygen is dominating over

lower calorific value for better combustion. However, beyond B₁₀, the lower calorific value is the dominating factor due to presence of oxygen.

Brake Thermal Efficiency (BTE) for Biodiesel from Pongamia Oil

The variation of brake thermal efficiency is given in table and shown in the Fig. 5, which indicates that the BTE of Pongamia biodiesel is about 24% almost similar to that of diesel at full load condition.

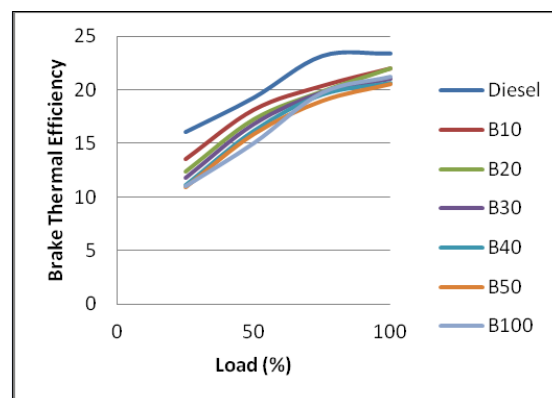


FIG. 5 VARIATION IN BTE WITH LOAD FOR DIFFERENT BLENDS BIODIESEL FROM PONGAMIA

TABLE 4 BSFC (G/KWH) AND BTE (%) OF BIODIESEL FROM PONGAMIA AND OTHER SOURCES

Properties Blends	BSFC (g/kWh)	% Change in BSFC	% Unsaturation	BTE (%)	Reference
B100(for Pongamia Biodiesel)	759	30.4	84.4	21.19	Experimental Result
B100(for Jatorpha Curcas Biodiesel)	651	12	78.9	22.15	[3]
B100(for WCB)	669	15	80.6	21.8	[3]
Diesel	582	0	0	23.39	Experimental Result

The BTE for biodiesel for all blends range (B₁₀ to B₁₀₀) was found almost comparable to that of diesel. Perhaps due to higher cetane number and inherent presence of oxygen in the biodiesel produced better combustion. In addition the Pongamia and its blends have lower viscosity. The reduction in viscosity of Pongamia leads to improved atomization, fuel vaporization and combustion. The ignition delay time is also close to diesel. The BTE for B₁₀ (22.08), B₂₀ (22) and B₃₀ (21.03) was found about nearly equal to diesel (23.39) respectively. The low efficiency may be due to low volatility, slightly higher viscosity and higher density of the biodiesel of Pongamia oil, and also due

to presence of higher unsaturation in Pongamia biodiesel which affects mixture formation of the fuel and thus leads to slow combustion. The table 4 shows the comparative analysis of BSFC and BTE for the various biodiesel at full load

From the table 4 the BSFC in case Jatropha biodiesel and Waste Cooking biodiesel is less by 14.2 % as compared to Pongamia biodiesel. This is due to the fact that engine consumes more fuel with diesel-biodiesel blend fuels than with neat diesel fuel to develop the same power output due to the lower calorific value of diesel-biodiesel blend fuel and other reason is attributed to percentage unsaturation in the molecules of biodiesel. The BTE of Pongamia is 12-13 % lower as compared to JCB and WCB. A slight lower efficiency with diesel was reported for the biodiesel due to the lower heating value of the biodiesel than with diesel and also due to presence of higher unsaturation in Pongamia biodiesel. This indicates that the percentage unsaturation in biodiesel has significant effect on BSFC and BTE thereby affecting the performance of the engine significantly. The result shows that the performance of engine in terms of BSFC is significantly affected by percentage unsaturation in biodiesel molecule. It was found that as the percentage unsaturation in biodiesel increases the BSFC also increases leading to more fuel consumption. This is the reason that biodiesel from different oil sources will perform differently during engine operation. This aspect will open a new area of R&D to establish relationship between percentage unsaturation in biofuels and BSFC of engine.

Exhaust Gas Emissions

TABLE 5 EMISSION RESULT OF VARIOUS BLENDS OF PONGAMIA BIODIESEL

Blends Emission	B ₁₀	B ₂₀	B ₃₀	B ₄₀	B ₅₀	B ₁₀₀	Diesel
CO Emission (%)	0.37	0.34	0.30	0.28	0.25	0.10	0.40
NO _x Emission (ppm)	3.81	3.87	5	6	7	4	3
HC Emission (ppm)	10.1	8.3	7.9	7.2	6.1	5.6	11.2

Exhaust Emission was measured by an AVL gas analyser and a smoke-meter. The sensor of the analyser was exposed to the engine exhaust and the observations were recorded. The result is given in table 5 for the CO, HC and NO_x emission. Greenhouse emissions, like carbon dioxide emission, showed a large reduction for all blends as compared to neat petroleum based diesel fuel.

The CO and HC emissions are drastically reduced by increasing the percentage of biodiesel as shown in table 5. NO_x emissions for the case of Pongamia biodiesel were lower at 100% load. These lower NO_x emissions could be due to lower temperatures in the combustion chamber using Pongamia blends. The BSFC for all type of blends of Pongamia biodiesel is higher than JCB and WCB while the BTE for B₂₀ & B₃₀ shows almost similar efficiency to that of diesel and the exhaust gas emission in case of biodiesel is less compared to diesel while NO_x emission is more in case of biodiesel except B₁₀₀.

Conclusion

The present study has dealt with the production of biodiesel from Pongamia oil, measurement of properties and performance evaluation of 2 kVA DG set on blends of biodiesel at various loads. The following conclusions can be drawn. The fuel properties like density, flash point, viscosity and calorific value of B₁₀, B₂₀ are very similar to diesel and therefore diesel may be well replaced by biodiesel in near future. The performance evaluation of engine has found that BSFC for B₁₀₀ in case of Pongamia biodiesel was 30.4 % higher than diesel at full load, thereby indicating that more amount of B₁₀₀ produce power similar to diesel. This makes the fuel to become the "On Farm Fuel" where farmer can grow his own resource, convert to biodiesel and use in agricultural sets itself without the need of any diesel for blending. The low efficiency may be due to low volatility, slightly higher viscosity and higher density of the biodiesel of Pongamia oil, which affects mixture formation of the fuel and thus leads to slow combustion.

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